Can young children benefit from collaborative problem solving? Tracing the effects of partner competence and feedback

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Abstract:

This research was designed to ascertain the extent to which and the conditions under which 5- to 6-year-olds benefit from collaborative problem-solving. We were interested in the impact of (a) repeated collaborative sessions, with the problem difficulty tied to the current independent ability of the target children; (b) working with a more competent partner, an equally competent partner, or with no partner; and (c) immediate feedback from the materials. The data (obtained from a sample of 81 children) revealed that collaboration with a more competent partner was more beneficial than working alone or working with an equally competent partner, but only when feedback was not provided. With feedback, singletons improved more than those who worked with a partner, irrespective of the partner's relative competence. No benefits were found for repeated collaborative sessions; improvement occurred early and then levelled off. The results are set in the context of Piagetian and Vygotskian theory, and serve to illustrate that with regard to peer collaboration these theoretical positions are complementary rather than in opposition.

Keywords: Peers | collaboration | problem-solving | feedback

Article:

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The impetus for this study arose from a number of questions regarding the relations between social and cognitive development in children in their first year of school - specifically about the extent to which and the conditions under which they can benefit from collaboration with their peers. The questions focused on in this study are as follows. First, can children of five to six years of age benefit from problem-solving if given the opportunity to collaborate over repeated sessions? Second, given this opportunity, what are the effects of immediate feedback (direct demonstration of whether their problem-solving predictions are right or wrong) on the outcomes of collaborative work? Third, when collaborating partners vary in initial competence levels do children with more competent partners benefit more from collaboration than children with partners of equal competence?

These questions have both practical and theoretical significance. At the practical level, their relevance has to do with the selection of appropriate teaching practice with young children in schools. Should teachers use methods that promote collaborative learning? What can they expect from grouping together children of differing competence levels? Would it be important to ensure that children collaborate repeatedly over time? How important is feedback from task materials to the learning process?

These questions are of no less interest from a theoretical point of view. The belief that social factors and cognitive development are linked in complex ways has been espoused by a number of different theorists, including Piaget and Vygotsky (Azmitia & Perlmutter, 1989; Tudge & Winterhoff, 1993). Although much comparative work has tended to treat these two theorists as if they were in opposition, what Piaget and Vygotsky had to say about the links between collaboration and development are almost complementary; taken together, they both contribute to furthering our understanding. For example, Piaget argued strongly that peer discussion (or 'socio-cognitive conflict' in the terminology used by some Piagetian scholars) is a critical factor in cognitive development (Piaget, 1959, 1977). Piagetian scholars interested in the effects of peer interaction have provided evidence for the benefits accruing to the less competent of two same-age partners (e.g., Doise & Mugny, 1984; Murray, 1982; Perret-Clermont, 1980). Similarly, Vygotsky suggested that children can benefit from collaboration with more competent peers if assistance (in the form of discussion or demonstration) is provided within their 'zone of proximal development' (Vygotsky, 1978, 1987) and empirical support for this position has also been found (e.g. Forman, 1987; Forman & Cazden, 1985; Gauvain & Rogoff, 1989; Martin, 1985; Rubtsov, 1981; Tudge, 1992).

Thus there is broad theoretical agreement that peer collaboration may lead to cognitive development. However, the role played by the status of collaborating partners (their respective levels of competence), the age at which children are likely to benefit from collaboration, and whether or not feedback is required are specific aspects related to collaboration that may reveal discrepancies in theoretical positions.

Competence and status

One apparent disagreement is that Piaget (1932, 1977) believed that collaboration between peers (i.e. children at a similar level of status) was more effective than adult-child collaboration, whereas Vygotsky (1987) argued that collaboration required the presence of a more competent partner, whether adult or child. This disagreement may be more apparent than real, however, for it is clear that the problem that Piaget had with adult-child interaction related to situations in which the adult simply acted as an authority figure over the child. Piaget (1977) argued that adults could serve as effective partners to children to the extent to which they were able to 'efface' themselves in their dealings with children. Both theorists believed that collaboration was most likely to be effective when both participants share the goal of attaining joint understanding, and that resolution of a difference in perspectives or problem solving strategy was the key to development, rather than disagreement *per se* (Tudge & Winterhoff, 1993).

The empirical evidence regarding partner competence and status is not particularly consistent. For example, Rogoff and her colleagues, working within a Vygotskian framework (Ellis & Rogoff, 1982, 1986; Radziszewska & Rogoff, 1988, 1991) indicated that children paired with adults performed better on subsequent individual tests than those paired with other children, whether or not the child's partner was more competent than the child. Gauvain and Rogoff (1989), however, found no such differential benefits for children who had worked with an adult. Other researchers, typically Piagetian (who have concentrated only on child-child performance), have found that collaboration with a more competent (but same status) partner is effective in bringing about cognitive growth (Doise & Mugny, 1984; Perret-Clermont, 1980; Perret-Clermont, Perret, & Bell, 1992; Tudge, 1989, 1992).

Age

With regard to the age at which children may be expected to benefit from collaboration, Piaget argued (in a paper first published in 1945) that children are not capable of truly benefiting until they are in the stage of concrete operational thinking (Piaget, 1977) - but also stated that children attain concrete operational thinking in part as a result of peer discussion (Piaget, 1959). Vygotsky stated that ontogenetic development from the start occurs on the social plane before becoming individual (Vygotsky, 1978), but did not necessarily mean by this that *peer* collaboration is an effective impetus to development from birth.

Here, too, the evidence is not much clearer, because most of the research on the benefits of collaboration has been conducted with school-age children. Some scholars have indicated that children of five years and younger can work collaboratively and benefit from the process (Azmitia, 1988; Brownell, 1990; Perlmutter, Behrend, Kuo, & Muller, 1989; Tudge, 1985, 1992), although there is still debate about the extent to which younger children can benefit (Azmitia & Perlmutter, 1989; Koester & Beuche, 1980).

Under what conditions are children younger than 6 or 7 most likely to benefit from collaboration? The vast bulk of the work examining the effects of collaboration on development have been of the single 'treatment' (collaborative) session type, typically with a pretest and one or two posttests. However, a number of scholars have argued that (particularly when working with young children) a 'stable working style' needs to be established before the benefits of collaboration are likely to be seen. For example, having worked with 5-year-olds, Azmitia (1988) argued that researchers need to allow children of this age time to become comfortable working together before examining the nature and consequences of their collaborations. Especially for young children, the requirement for social negotiation may detract from their ability to focus on the task demands. Azmitia argued that once children establish a stable working style the demands of solving the task may become of more interest. It may be that 'greater engagement, enjoyment, consideration of alternatives, and persistence' result from the interaction of well-established dyads, and that these features contribute to meaningful learning for young children (Azmitia & Perlmutter, 1989, p. 113). In a similar vein, Aboud (1989; Nelson & Aboud, 1985) emphasized that the benefits of greater task engagement and productive disagreement are more likely to come when collaborating partners are friends. They suggested that once children have become friends the nature of their collaborations is likely to differ from those of non-friends.

Azmitia's (1988) research allowed dyads comprising 5-year-olds of varying ability levels two sessions in which to establish a 'working style' together. Perlmutter and her colleagues (1989), in the second of three related studies of young children's collaborations on computer tasks, provided children with six repeated problem solving sessions for dyads and individuals, thereby hoping to ensure the establishment of a stable working style. Two age groups were involved in the study, one with an average age of 53 months, and another with an average age of 65 months. An important finding of this work was that there seemed to be an interaction between task difficulty and the older group's ability to benefit from collaboration. For this age group, collaboration was helpful with tasks of low complexity, but of little benefit when the task was more complex. 'This pattern suggests that the primary constraint on the benefits of peer interaction may be task competence, which often increases with age, rather than age or developmental level per se' (Perlmutter *et al.,* 1989, p. 753). However, as we shall argue below (in the results and discussion sections), time taken to establish a stable working style is confounded, particularly in the first year of school, with experience in school.

Feedback

Regarding feedback, both Piaget and Vygotsky believed that it was essential to development; Piaget primarily discussed feedback from the physical world (discrepancies encountered by children in the course of their active involvement with the world of material and logical objects), but also conceded that resolution of discrepancies in perspective with a social partner also aided development. Disequilibrium occurs as children encounter a discrepancy between their current structures of thought and the materials with which they are actively engaged. In essence, they are receiving feedback as a result of their activities.

Vygotsky did not explicitly discuss feedback, but he clearly recognized its importance; the type of fine-tuned interaction that has to take place to allow joint understanding to be attained requires a good deal of feedback (Rogoff, 1990; Valsiner, 1987; Wertsch, 1985). From a Vygotskian position, collaboration with more competent social others is likely to lead to development when assistance is provided within the less competent partner's zone of proximal development – in other words, the assistance is such that the child is helped to work collaboratively on problems somewhat in advance of problems that he or she can solve independently. Vygotsky's position was that feedback from the social world was imperative; however, interaction with social partners is always mediated by tools (both psychological and physical). Moreover, although Vygotsky for the most part discussed interactions in the zone of proximal development in the context of teacher-child interactions, he also (Vygotsky, 1978) argued that in solitary play a child in effect may create a zone of proximal development (Nicolopolou, 1993). The same might be true when a child works alone on a problem that is slightly more difficult than he or she can manage independently, but receives feedback from the materials.

Little empirical evidence relates to the impact of providing feedback, because scholars have not explicitly compared what happens when collaborating partners (as opposed to children working alone) are provided (or not provided) feedback. Indeed, the neo-Piagetian research on the impact of peer collaboration on the attainment of conservation cannot include explicit feedback, given that what counts as evidence of conservation to a conserver does not have the same meaning to a non-conserver. By contrast, researchers in the Vygotskian tradition virtually assume a measure of feedback, typically provided by the more competent partner. The assumption, of course, is that the more competent partner actually provides assistance (in effect feedback) that makes sense to the less competent partner; however, this situation may more rarely occur when pairs of children work together on a problem than is the case for adult-child dyads. There is no guarantee that simply because one child is more competent than another he or she will actually articulate aspects of the problem or solution likely to help the less competent child (Tudge, 1992). Moreover, even if feedback is provided it may not be seen as helpful if (as in the case of non-conservers) its relevance is not obvious.

Given the lack of research evidence, however, closer examination of the effects of feedback on collaborative outcomes seems imperative. As Wolters, Fischer, and Zuidema (1987) have pointed out, a no-feedback situation is quite uncommon in elementary or infant school classrooms. Virtually every learning encounter between peers in classrooms eventually includes some form of feedback about the correctness of answers or the competence of performance.

The research undertaken in this study was therefore designed to further examine the processes and consequences of collaboration among five to six-year-old school classmates of varying levels of competence by: (1) allowing children to work together on multiple occasions, so as to provide the opportunity for a 'stable working style' to be established; (2) either providing or not providing immediate feedback from task materials; and (3) by 'pegging' the content of treatment problems to the competence levels of target children.

Hypotheses

(1) That children of this age (5- to 6-year-olds) would show evidence of improved thinking about the task as a result of working together.
(2) That children receiving feedback would improve more, over the course of the study, than those who did not receive feedback.
(3) That children whose partners were more competent would improve more than those whose partners had begun the study using the same rule and than those who worked without a partner.
(4) That the pattern of improvement, among those who improved, would not be continuous. Among those who improved, the greatest gains would be made toward the end of the study, as pairs achieved a 'stable working style' (Azmitia, 1988).

Method

Participants

A total of 81 children participated in the research, of whom 40 were female (mean age 69.9 months, ranging from 60 to 86 months) and 41 were male (mean age 70.0 months, ranging from 61 to 82 months). The children were drawn from four kindergarten classes in an open-enrollment public elementary school in Greensboro, NC, and consisted predominantly of white children from a mix of social classes. Testing took place in the school library, in a secluded area.

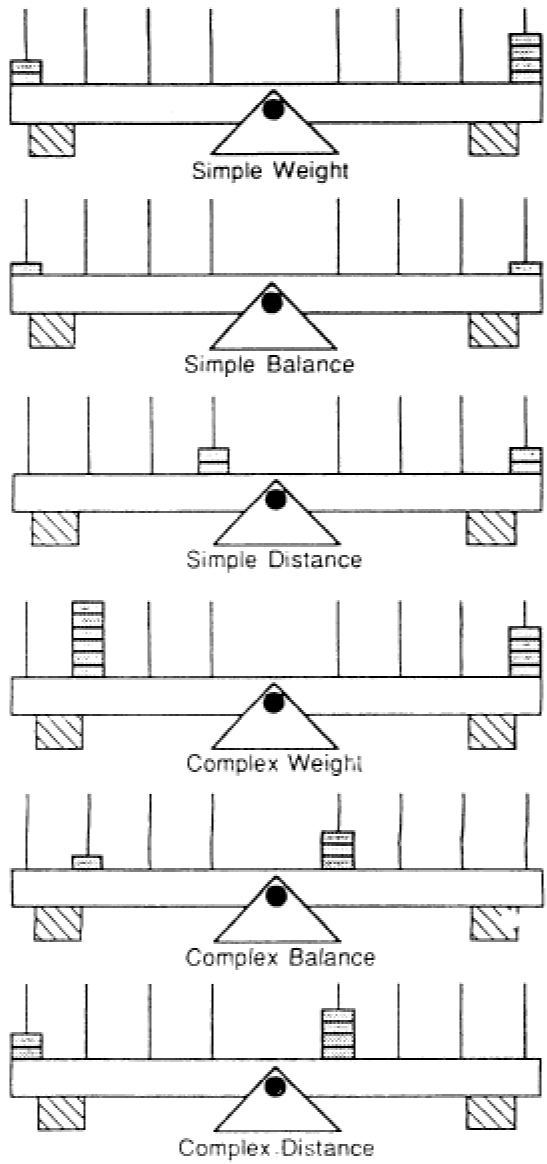

Figure 1. Examples of the six types of balance beam problems.

Materials

A mathematical balance beam (see Figure 1) was used, similar to that developed by Siegler (1976, 1981) and employed by Tudge (1992). This task was used because it identifies a number of different 'rules' that children use to predict the workings of the beam, where each rule requires thinking that deals with the relevant variables in a more sophisticated way than lower rules, and because no children of the ages of interest were likely to be at ceiling.

The beam had eight removable sticks placed at equal distances from the central fulcrum, and was held stable by wooden blocks supporting it at both ends. The blocks were removable to allow the children to observe free movement of the beam at the start of the experiment, but thereafter were only removed when feedback was provided. Metal nuts (each weighing the same) which fitted over the sticks were used as the weights in the treatment sessions.

The configurations of weights and distances for each of the individual (nontreatment) sessions consisted of 14 different problems in each set, each set including four simple distance problems and two each of five other 'problem types' (see Figure 1). In each case, the weights were placed on only one stick on each side of the fulcrum, with a maximum of six weights on any one side and a maximum of ten on both sticks.

Procedure

The design of the study may best be described as 'mini-longitudinal' in that each child participated in eight different sessions spread over a two-month period. Five of these sessions focused on independent performance (the final individual session being delayed), and three were 'treatment' sessions in which many of the children worked collaboratively and half received feedback. The design thus took the form: I T I T I T I I, where I represents an individual session and T a treatment session.

The initial individual test established which rule each child used to predict the movement of the balance beam when different numbers of weights were placed at varying distances from the fulcrum. Tudge (1992) identified seven rules (see below) which children use to predict the movement of a balance beam when different numbers of weights are placed at varying distances from the fulcrum. The rules range from simple guesswork, with no consistent attempt to consider either number of weights or distances, to the ability to predict precisely what will happen when any configuration of weights is placed on the beam.

Approximately one week later (M = 6.95 days, SD = 3.5 days), randomly designated 'target' children were assigned to be (a) paired with another child who used the same rule at that first session (n - 12), (b) paired with another whose initial rule was higher (n = 20, or (c) to work without a partner throughout (n = 15). All dyads were from the same classroom and of the same gender. During the first 'treatment' session children were given eight problems that varied systematically in terms of numbers of weights and distances from the fulcrum, half of which were solvable by the rule that the child had independently used, the remainder designed to be somewhat more difficult (solvable by use of the next higher rule). Pair members took turns to predict the movement of the beam. In the case of disagreements, the experimenter pointed out that both answers could not be correct, and asked the children to talk about the problem until they had decided on 'just one answer'. At this point, he left the area, returning when the children signalled that they had reached agreement. After agreement was reached, half of the participants were provided with feedback (the experimenter removed the blocks that held the beam in place so that the children could see if their answer was correct), and half were not.

Several days later (M = 4.20 days, SD = 2.76 days), the children were then retested individually, using a new set of 14 problems that, like those used in the first session, covered the entire range of problem types. A few days after that (M = 5.39, SD = 2.43), they again worked collaboratively with their partner. As in the first treatment session, half of the problems presented were chosen to be slightly in advance of those that target children had solved correctly in the previous individual session, the remainder being solvable by the rule used in that session. A third individual session was followed by a third treatment session which was again followed by an individual session (Ms = 4.32, 5.64, and 3.34 days, respectively). Finally, the last individual session took place about one month (M = 29.93 days, SD = 7.92) after the previous session. (Classroom schedules, holidays, and children's illnesses, together with the necessity for having to work with pairs, accounted for the rather high variability in number of days between sessions. However, there was always a minimum of one day between sessions for the target children who are the focus of this paper, with the exception of the delayed individual session where the minimum number of days was 17.)

Assignment to rule. Rule 0. No understanding either of the idea of balance or of what will happen when one side of the beam has more weights. Of the 80 children who participated in all phases of the study, nine used this rule (mean age 68.2 months, range 62-74 months) in the initial individual session.

Rule 1. Children using this rule consistently predict the side that has the greater number of weights will tip down (simple weight and all complex problems, see Figure 1), but inconsistently guess either one side or the other for problems with equal weights (simple balance and distance problems). Three children, mean age 72.0 months, range 67-77 months, used this rule initially.

Rule 2. Children using this rule consistently predict the side that has the greater number of weights will tip, and that the remaining problems will balance. Twenty-seven children, mean age 68.2 months, range 62-77 months, used this rule initially.

Rule 3. Children using this rule consistently predict that the side with the greater number of weights will tip, and that the simple balance problems will balance. Their predictions about the four simple distance problems are inconsistent, however; when the difference in distance is great (for example, one set of weights at the end and the other close to the fulcrum) they are likely to take account of distance, whereas if the difference in distance is small they will not. Twenty-seven children, mean age 69.9 months, range 60-80 months, used this rule initially.

Rule 4. Children using this rule consistently predict that the side with the greater number of weights will tip, that the simple balance problems will balance, and that the simple distance problems will tip to the side furthest from the fulcrum. Children using this rule simultaneously consider the variables of number and distance when the numbers are equal but the distance is not. Five children, mean age 73.8 months, range 69-83 months, used this rule initially.

Rule 5. Children using this rule predict consistently (and correctly) for all the simple problems, but predict inconsistently for the complex problems. Children using this rule view distance as important even when the numbers of weights are different, but sometimes predict that the complex problems tip to the side with greater number, sometimes to the side with greater distance, and sometimes balance - and make their decision by guesswork. One or more predictions in which a child argued that distance was as or more important than numbers of weights on the complex problems was sufficient to classify that child as using Rule 5, assuming that the remaining predictions were appropriate to Rule 4. Nine children, mean age 75.0 months, range 62-86 months, used this rule initially.

Rule 6. This rule features an understanding of what will happen in each problem, gained by multiplying the number of weights by the distance from the fulcrum. All configurations can be consistently and correctly predicted. No children used this rule.

To ascertain which rule children used required examination of the entire pattern of predictions and justifications to all 14 problems. A minimum of 12 of 14 problems was used to classify a child; one or two predictions, at variance with the remaining pattern, was insufficient to move a child to the next lower rule. However, one discrepant prediction was sufficient to move a child to the next higher rule so long as the child justified that prediction appropriately. For example, a child whose predictions were based solely on number of weights would be coded as using Rule 2; if that child predicted that just one of the simple distance problems would tip to one side or the other, and mentioned distance as part of her justification, she would be coded as using Rule 3. On the other hand, predicting that the beam would tip, but providing an irrelevant justification (a mis-count, for example), would not lead to that child being coded Rule 3.

All sessions were videotaped, and the individual sessions were coded independently by two coders, one of whom was blind to the status and condition of the children. Interrater reliabilities were consistently high (kappas for each session ranged from .85 to .93), and disagreements were discussed until agreement was -reached.

Results

Of the 81 participants, 48 were 'target' children, of whom one did not complete the full series of sessions and was therefore dropped from analyses. These children were either singletons, who never worked with a partner, or dyadic members whose partners have been excluded from these analyses to ensure independence of the units of analysis. Of these 47, 24 were boys (mean age 70.75 months, range 62-82 months) and 23 were girls (mean age 69.61 months, range 62-77 months). As gender did not exert any significant influence on the data to be discussed, either in terms of initial rule use or degree of improvement, it was not included in the analyses to be discussed below.

The full analysis consisted of a 3 (Partner: no partner, equally competent partner, more competent partner) × 2 (Feedback: provided, not provided) × 5 (Time: the five individual sessions) multivariate analysis of variance (MANOVA), using a multivariate approach to the analysis of repeated measures (Maxwell & Delaney, 1990). The five individual sessions constituted the within-subjects part of the analysis, feedback and partner the between-subjects factors.

Improvement over time

Time exerted a significant effect (Wilks' lambda F (4, 38) = 5.52, p < .002), revealing that over time these participants significantly altered their patterns of rule use. The mean score for rule use (with 0 given for use of no rule at all, 1 for Rule 1, 2 for Rule 2 and so on) at the first individual session was 2.04 (SD = 1.20). Mean improvement scores (where 0 indicates no change from that first session) were 0.66, 0.66, 1.02, and 0.77 respectively at the 2nd, 3rd, 4th and 5th individual sessions. These improvements from the first session were each significant *(ps* < .005). Ignoring the singletons who worked without a partner, the degree of improvement was significantly greater than zero *(ps* < .01) at each subsequent individual session, thereby supporting Hypothesis 1, that children of this age can benefit from working together.

Impact of feedback

The MANOVA also revealed that there was a significant time by feedback interaction (Wilks' lambda F (4, 38) = 4.99, p < .003), indicating that the degree of improvement over time differed as a function of receiving, or not receiving, feedback from the materials. As displayed in Table 1, the children who received feedback improved far more than those who did not, a finding in support of Hypothesis 2. Ignoring feedback, the impact of working alone, with an equally competent, or with a more competent partner did not lead to significant differences in individual performance; the interaction of time by partner was not significant (Wilks' lambda F (8, 76) = 1.60, p > .1). However, the interaction of time by feedback by partner was significant *(F* (8, 76) = 2.30, p < .03). (We should stress that these results, whether main effects or interactions, are all independent of the effects attributable to the other factors).

Table 1. Mean rale use (SD in parentheses) at pretest (Ind 1) and change from pretest at subsequent individual sessions, by feedback and partner status

Group	*N*	Ind 1	Δ Ind 2	Δ Ind 3	Δ Ind 4	Δ Ind 5
No feedback						
Singletons	7	2.43 (1.72)	-0.71^{+} (0.95)	–0.86 (1.21)	–0.86 (1.21)	–0.71 (1.38)
Equal rule p.	6	2.83 (1.73)	0 (91.10)	–0.17 (0.75)	0.17 (0.98)	–0.17 (0.75)
More comp p.	10	1.70 (1.25)	0.60^{+} (0.97)	0.80^{+} (1.14)	1.10^{a} (1.45)	0.70^{a} (0.95)
(Combined)	23	2.22 (1.41)	0.04 (1.11)	0.04 (1.26)	0.26 (1.48)	0.04 (1.19)
Feedback						
Singletons	8	1.38 (1.30)	2.25^{c} (1.16)	1.75^{a} (1.67)	2.25^{b} (1.67)	2.25^{c} (1.19)
Equal rule p.	6	2.83 (0.75)	1.17^{a} (0.98)	0.83 (1.47)	1.83^{c} (0.75)	0.50 (1.05)
More comp p.	10	1.70 (1.06)	0.50 (1.27)	1.10^{a} (1.37)	1.30^{a} (1.57)	1.40^{a} (1.51)
(Combined)	24	1.88 (1.19)	1.25^{c} (1.36)	1.25^{c} (1.48)	1.75^{d} (1.45)	1.46^{d} (1.50)

Two-tailed t tests for dependent samples, comparing the posttest-pretest differences to zero (no change from pretest): $^{+}p < .10$; $^{a}p < .05$; $^{b}p < .01$; $^{c}p < .005$; $^{d}p < .0001$.

Impact of partner type, by feedback

In order to focus more clearly on the ways in which the impact of partners varied by whether or not the children received feedback, we converted the scores into difference scores (degree of improvement or decline from the initial individual session), and examined separately those who received feedback and those who did not. The model thus included type of partner and the initial individual session, which was included as a covariate to control for the children's initial levels. For those *without feedback,* the differences from the initial session were as follows: *(F* (2, 19) = 2.86, p < .09; F *(2,* 19) = 4.44, p< .03; F *(2,* 19) = 4.98, p < .02; F (2, 19) = 3.68, p < .05 at the time of the second, third, fourth, and final individual sessions respectively. Tukey's HSD test indicated that at each time the children who worked with a more competent partner benefitted significantly more than children who worked always as singletons, as predicted by Hypothesis 3. As Table 1 indicates, children who worked with a more competent partner also improved more than those who worked with an equally competent partner, but this difference was not significant. To put the position in slightly different terms, six of the 10 children paired with a more competent partner improved in their thinking by the time of the final individual session, and only one declined. By contrast, only one of the 13 target children in the other two groups improved, whereas five declined.

However, the results were quite different for the group of children *with feedback;* 18 of the 24 target children improved by the time of the final individual session. Identical analyses were performed. The impact of type of partner was again significant (F (2, 20) = 4.58, p < .05), but only when considering changes from the first to the second individual session. Type of partner did not significantly affect individual performance at later sessions (*ps* > .2). Tukey's HSD test also indicated that children who worked with a more competent partner differed significantly only from those who worked without a partner (only considering changes from first to second session). However, as Table 1 indicates, the changes were the opposite of those predicted in the third hypothesis – singletons actually improved more than those who worked with a competent partner.[1]

Impact of stable working style

The fourth hypothesis stated that greater improvements, at least for those children who improved, would be found towards the end of the study than at the start; that is, after a stable working style had been established. To test this hypothesis, the data were re-analyzed in such a way that a comparison could be made of degree of improvement (or decline) from each individual session to the subsequent session (rather than changes from the first individual session, as presented in Table 1).

A 2 (feedback) × 3 (partner) analysis of covariance (ANCOVA) was therefore run on the difference scores, the covariate being the score obtained on the first individual session (to control for the rule used at that first session). This analysis revealed that the major differences in performance occurred from the first to the second individual session, but not thereafter. Feedback exerted a significant effect (F (1, 40) = 15.57, p < .0004), partner (as a main effect) did not (F (2, 40) = 0.45, p > .6), but again there was a significant interaction of feedback and partner (F (2, 40) = 7.25, p < .003).

[1] As is clear from Table 1, the six groups differed in their initial level of rule use. To ensure that the results are not attributable to these initial differences, the data were re-analyzed using a subsample consisting only of those target children who initially used either Rule 2 or 3. In this sub-sample, the mean initial rules for each of the six groups were very similar, ranging from 2.29 to 2.60, but the pattern of improvements and declines was highly similar to that shown in the full sample. Thus among those without feedback the singletons declined, those with an equally competent partner continued to use the same rule, and those whose partner was more competent improved. For those with feedback, all improved much more than their peers who did not receive feedback, particularly those who worked alone.

However, these significant effects were only found when examining the change from first to second individual session. For those children who received no feedback (across type of partner), the increase (or decrease) in score from one individual session to the next was as follows: 0.04, 0, 0.22, and -0.22, none of which were significantly different from 0 (no change from the previous session). For those children who received feedback, the respective changes were 1.25, 0, 0.50, and -0.29, of which only the change from first to second session showed a significant degree of improvement (t (23) = 4.50, $p < .0003$).

To tease apart the significant interaction effect in the test of stable working style, we again analyzed separately those who had received feedback and those who had not. Not surprisingly, the effects were identical to those reported above; children who did not receive feedback benefitted from working with a more competent partner, although all the gains occurred at the first paired session rather than subsequently. Similarly for those who received feedback; singletons gained significantly more from the initial feedback than children who worked with partners, but not following subsequent feedback. There was thus no evidence to suggest that either working repeatedly with the same partner or getting repeated feedback from the material had any cumulative effect after the first treatment session. These data thereby provided no support for Hypothesis 4, that children need to develop a stable working style (operationalized as two or more opportunities to collaborate) before showing any benefit of collaboration.

However, stable working style, as we mentioned earlier, may be confounded with both age and time in school - an issue of particular concern to those working with children in their first year of formal schooling. These data, fortuitously, allowed us to tease apart age and time in school. Although all the children were drawn from kindergarten classes, children in two of the four classes participated in the study during the autumn term (shortly after entering kindergarten) and others participated during the spring term. It was therefore possible to examine the effects of experience in school (separate from age *per se*). Not surprisingly, the children who had been in school longer were older, on average, than those who were less experienced school attenders (72.0 months vs. 67.2 months, t (46) = 3.70, $p < .0005$). However, the spread of ages in the two groups (67-82 months in the experienced group, 62-77 months in the inexperienced group) was sufficiently large to examine separately the impact of age and experience in school.

Dividing the children by a median split on age revealed that the younger group (n = 25, M = 66.4 months, SD = 2.40) did not differ significantly from the older group (n = 22, M = 74.5 months, SD = 3.07) in terms of rule use at the initial individual session (M = 1.92, SD = 1.35 and M = 2.18, SD = 1.26 respectively, t (46) = -0.68, $p > .4$), or in terms of subsequent changes from initial rule use.

On the other hand, dividing the children by relative experience in school revealed a somewhat different picture. As Table 2 indicates, the more experienced group used a much higher rule, on average, at the time of the initial individual session (M = 2.45, SD = 1.15 and M = 1.39, SD = 1.29 respectively, t (46) = 2.93, $p < .006$). Moreover, the degree of improvement by the time of the second individual session was greater for the experienced group than for the inexperienced group (M improvements = 0.79, SD = 1.37 and 0.44, SD = 1.38 respectively) though not significantly so. In fact, the more experienced group continued to make slightly larger gains than the inexperienced group until the final individual session, when the less experienced group improved from their initial rule somewhat more than their more experienced counterparts.

Table 2. Mean rule use (SD in parentheses) at pretest (Ind 1) and change from pretest at subsequent individual sessions, by school experience and feedback

Group	*N*	**Ind 1**	**Δ Ind 2**	**Δ Ind 3**	**Δ Ind 4**	**Δ Ind 5**
Experienced						
No feedback	15	2.60 (1.12)	0.07 (1.22)	–0.07 (0.96)	–0.07 (1.03)	–0.27 (0.80)
Feedback	14	2.29 (1.20)	1.57[d] (1.09)	1.57[c] (1.45)	2.21[d] (1.12)	1.71[c] (1.38)
(Combined)	29	2.45 (1.15)	0.79[c] (1.37)	0.72[a] (1.46)	1.03[c] (1.57)	0.69[a] (1.49)
Inexperienced						
No feedback	8	1.50 (1.69)	0 (0.93)	0.25 (1.75)	0.88 (2.03)	0.63 (1.60)
Feedback	10	1.30 (0.95)	0.80 (1.62)	0.80 (1.48)	1.10[+] (1.66)	1.10[+] (1.66)
(Combined)	18	1.39 (1.29)	0.44 (1.38)	0.56 (1.58)	1.00[a] (1.78)	0.89[a] (1.60)

Two-tailed *t* tests for dependent samples, comparing the posttest-pretest differences to zero (no change from pretest): [+] $p < .10$; [a] $p < .05$; [b] $p < .01$; [c] $p < .005$; [d] $p < .0001$

Most interesting, however, were the different patterns for the children who received feedback and those who did not. As Table 2 makes clear, the relatively inexperienced children improved somewhat over time, without feedback, whereas the more experienced children did not. On the other hand, the differences between those who received feedback and those who did not were only significant among the group of more experienced children. Looking first at the group of inexperienced children, those who would receive feedback did not differ significantly from their peers who would not at the initial individual session ($t(17) = 0.30$, $p > .7$). The relative improvement of these two groups was not significantly different at any subsequent session (*ps* > .2). For the group of children who were experienced in school, at the initial individual session those who would receive feedback were not significantly different from those who would not ($t(28) = 0.73$, $p > .4$). However, the degree of improvement among those who received feedback was significantly greater at all subsequent session (*ps* < .002). The primary questions of this study related to whether or not young children can benefit from collaboration and the impact of partner competence and feedback. These questions clearly have relevance for early educational practice, but are also of theoretical significance. Piaget and Vygotsky are the two theorists whose ideas have been most widely used by scholars interested in the relations between collaboration and cognitive development. This study furthers the productive dialogue between the developmental theories of Vygotsky and Piaget.

Focusing first on age - the participants in this study were aged between five and six years old. Although Piaget believed that the greatest benefits from peer interaction would be attained after children have reached concrete operational thinking, he also felt that discussion and socio-cognitive conflict between peers were likely to help them attain that stage of thought, assuming that resolution of that conflict was achieved. Vygotsky believed that social factors relate to individual development from birth, but held that collaboration was only likely to be successful to the extent to which intersubjectivity (joint understanding) was attained by the collaborating partners (Forman, 1987; Forman & McPhail, in press; Tudge, 1992; Wertsch, 1985). Do the data provided in this study indicate that children of 5 to 6 years of age can benefit from collaborative problem-solving, as predicted by the first hypothesis?

It is clear that many of these young children improved in their thinking; yet it is also clear that only in certain circumstances could this improvement be attributed directly to collaboration. The most striking effects related to feedback, with support for the second hypothesis; children, across presence or type of partner, who received feedback improved more than those who did not. Children clearly benefitted from seeing just how the beam 'behaved' during treatment sessions. The effects were immediate and stable.

Partner competence had an effect, but only in the absence of feedback. The third hypothesis, that those children who worked with a more competent partner would improve more than those who worked either with no partner or with a partner who had used the same level of thinking during the first individual session, was therefore not supported. There was, however, a significant partner by feedback interaction. The analyses revealed that target children who did not receive feedback and who worked with a more competent partner improved more than children in the other groups, significantly more than the singletons. Under conditions of no feedback children of this age can clearly benefit from collaboration with more competent partners. By contrast, of those who were given feedback, target children paired with initially more competent partners improved significantly less than children who worked alone. This finding was contrary to what had been hypothesized. It should be noted, however, that the significantly greater improvement of those who worked with a more competent partner (among those who did not receive feedback) persisted throughout the course of the study. The significantly greater improvement of singletons (among those who received feedback) only occurred between the first and second individual sessions.

What can one make of the fact that receiving feedback in conjunction with a more competent partner did not lead to the greatest degree of development? Surely the combination of a problem within the children's zone of proximal development and a partner who could explain the solution should have been particularly effective. However, simply pairing children at different levels of expertise is no guarantee that they will work together effectively or attain joint understanding. Among children of this age, the opportunities afforded by being paired may be seen by some not as an impetus to collaboration on the task but as the means to 'play around'. This points to the necessity to analyze the collaborative *processes.* These analyses will allow an assessment of the extent to which attaining joint understanding is reflected in greater improvement. It is important to stress the fact that these analyses relate only to the outcomes of collaboration, not the collaborative processes themselves. What have been reported are mean change scores over time. As has been argued elsewhere (Tudge, 1992), simple outcome data may not reveal the whole story with regard to the benefits or detriments of collaborative interaction. The mean group differences obtained in this study, large and significant though some of them were, may disguise sub-groups of children who performed differently from their fellows. Further coding and analysis will be necessary to uncover within-group differences.

It is also important to note that the comparisons are not between some children who are working in a social context and others who are in some sense removed from that context. The singletons did not have the opportunity to work with a partner; they were, however, with the experimenter, and the problems on which they were working had been carefully tailored to their current abilities and slightly in advance of those abilities. The social world, clearly, is as much a factor for these children as for those who worked with a partner. From a Vygotskian perspective, it is clear that a social partner is present even for singletons, although that partner's impact was not one of immediate interaction.

The fourth hypothesis concerned the impact of a stable working style. We found no support for this hypothesis, that greater benefits would become apparent towards the end of the study rather than during the early stages. This hypothesis was based on Azmitia's (1988) contention that peer collaboration is likely to be most effective once a stable working style has been established among partners. In fact, to the extent that benefits did accrue (primarily among children who received feedback), the effects appear to be initially striking but then to level off. From both Piagetian and Vygotskian theoretical positions this pattern of findings makes sense, however. From a Piagetian perspective, assuming that change from the use of one rule to another is evidence of accommodation, one would expect that the new equilibrium attained would be followed by a period during which children simply assimilated new information to the newly acquired rule. Vygotsky's (1987) discussion of interactions within the zone of proximal development makes quite clear that each child exhibits a potential for advancement through collaboration, but also that there are limits to this potential.

> We said that in collaboration the child can always do more than he can independently. We must add the stipulation that he cannot do infinitely more. What collaboration contributes to the child's performance is restricted to limits which are determined by the state of his development and his intellectual potential (Vygotsky, 1987, p. 209).

The dynamic interplay of collaborative effort leads to the mutual creation of limited zones in each child engaged in the work. These zones have *both* upper and lower limits. It seems apparent from this study that the upper limits of learning potential were reached by most of the collaborating partners after their first encounters and that, for this task at least, repeated collaborations did not lead to significant advances in development.

However, stable working style and age are confounded with experience in school. As children are developing a working relationship with their teachers and their peers they are simultaneously becoming more experienced in the expectations and requirements of school. In this study we were able to disentangle the confound of age and experience. Although this was not the subject of a hypothesis, it became clear that children with more experience in school (but *not* older children) used a significantly higher rule at the initial individual session than their peers with less experience and actually improved more at the second and third individual sessions. Moreover, children with greater school experience clearly and significantly benefitted from getting feedback in comparison to their peers who did not receive feedback. Of the children with less school experience, those who received feedback improved only slightly (and non-significantly) more than those who did not get feedback. The gradual improvement of the less experienced children who did not get feedback cannot be explained simply by maturation, for there was no corresponding improvement in the counterparts in the more experienced group.

Most contemporary research set within the Vygotskian theoretical framework has concentrated on the constraints and enablers of development contained within the immediate collaborative context. However, Vygotsky's theory also emphasized cultural influences on development (Vygotsky, 1978; Luria, 1976). One of the cultural influences that Vygotsky and Luria focused on was that of formal schooling, because of schooling's influence on ways of thinking. It may be the case that during the kindergarten year children are increasingly encouraged to use deductive, rule-based modes of thinking and to develop metacognitive strategies (Valsiner, 1989). It may be the case that the children in the inexperienced group were relatively less able than their experienced compatriots to use feedback to deduce a more sophisticated rule and use it in subsequent predictions. A second possibility is that one of the things that children learn in their first year of school is that they need to attend to and take seriously the tasks that they are given, rather than to treat them simply as play materials. This illustrates 'the connection between the performance of individuals on cognitive tasks and their experience with particular problem structures or genres through schooling' (Rogoff, 1990, p. 51). Stable working style, at least when applied to children in a new school setting, may therefore have less to do simply with repeated opportunities to collaborate and more to do with the development of understanding about the specific modes of working in this new setting. This point would apply equally to children in their first year of formal schooling and to those going to a new school that incorporates a different educational philosophy. Clearly, in order to understand the development of young children's thinking, connections must be drawn between socio-cultural institutions (such as school), the patterns of interaction and collaborative problem-solving fostered by those institutions, and individual characteristics.

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